Cairo Air Improvement Project

Air Quality Monitoring Component

1999 Baseline Lead Emissions Inventory for the Greater Cairo Area

Chemonics International, Inc.
USAID/Egypt, Office of Environment
USAID Contract No. 263-C-00-97-00090-00

September 2000

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Acronyms and Abbreviations

µg	Micrograms
AP-42	A collection of emission factor data published by the USEPA that provides average emission factors for various pollutants from various sources. The AP-42 emission factors are frequently used to estimate emissions when site-specific emission data is not available.
CAIP	Cairo Air Improvement Project
CAPMAS	Central Agency for Planning, Mobilization, and Statistics
Cu	Copper
EEAA	Egyptian Environmental Affairs Agency
FIRE	Factor Information Retrieval System
GOE	Government of Egypt
GOFI	General Organization for Industrialization
hr	Hour
kg	Kilogram
l	Liter
m, m^3	Meter, cubic meters
mg	milligram
OEP	Organization for Energy Planning
Pb	Lead
Sec.	Secondary
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency

1 Executive Summary

(Arab Abu Saaid not Included)

As part of the Cairo Air Improvement Project (CAIP), a 1999 lead emissions inventory has been completed for the greater Cairo area, including the governorates of Cairo, Giza, and Qaluobiya. The inventory and the associated database will assist in developing regulatory and control strategies, assessing emission trends, and conducting modeling exercises. This report describes the results of the emissions inventory.

As detailed in the report, it is estimated that the primary sources of lead emissions in the area emitted 2,307 metric tons of lead in 1999. The annual emissions from secondary lead smelters are estimated to be 1,815 metric tons, or approximately 78.7 percent of the total lead emissions from these sources. The annual emissions from the combustion of mazout in the greater Cairo area are estimated to be 477 metric tons, or approximately 20.7 percent of the total lead emissions from these sources. Emissions estimates are also provided for other sources as shown in Table 1 below. Emissions estimates for individual processes at these sources are included in the body of the report.

In addition to this report, a lead emissions inventory database has been developed. This database includes information on over two hundred facilities that emit lead into the air over greater Cairo. With annual updates, this database can serve as the tool to develop future lead emissions inventories that will highlight the results from ongoing efforts at reducing the emissions of lead in the greater Cairo area.

TABLE 1: 1999 LEAD EMISSIONS SUMMARY

Estimate of Lead Emissions from Major Sources in the Greater Cairo Area

Activity	**Number of Facilities**	**1999 Production**	**1999 Lead Emissions** (metric ton)	**Percentage of Total Lead Emissions**
Secondary Lead Smelting[1]	11	52,020 (metric tons lead ingot)	1,815	78.7%
Lead-Acid Battery Production[1]	33	416,600 (batteries)	3.41	0.14%
Secondary Copper Processing[1]	207	16,080 (metric tons)	8.04	0.34%
Portland Cement Manufacturing[1]	3	~13,500,000 (metric tons cement)	3.39	0.14%
Mazout Combustion[2]	Not Applicable	4,180,000 (metric tons mazout consumed)	477	20.7%
Total			**2,307**	**100%**

1. Production Data Source: CAIP survey.
2. Production Data Source: Ministry of Petroleum

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As detailed in the report, it is estimated that the primary sources of lead emissions in the area emitted 2,669 metric tons of lead in 1999. The annual emissions from secondary lead smelters are estimated to be 2,177 metric tons, or approximately 81.6 percent of the total lead emissions from these sources. The annual emissions from the combustion of mazout in the greater Cairo area are estimated to be 477 metric tons, or approximately 17.9 percent of the total lead emissions from these sources. Emissions estimates are also provided for other sources as shown in Table 1 below. Emissions estimates for individual processes at these sources are included in the body of the report.

In addition to this report, a lead emissions inventory database has been developed. This database includes information on over two hundred facilities that emit lead into the air over greater Cairo. With annual updates, this database can serve as the tool to develop future lead emissions inventories that will highlight the results from ongoing efforts at reducing the emissions of lead in the greater Cairo area.

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2 Introduction

2.1 Background

Pure lead is a silvery-white metal that oxidizes and turns bluish-gray when exposed to air. Its properties include a low melting point; ease of casting; high density; low strength; ease of fabrication; acid resistance; electrochemical reaction with sulfuric acid; chemical stability in air, water, and earth; and the ability to attenuate sound waves, atomic radiation, and mechanical vibration.[1] Lead in its elemental or pure form rarely occurs in nature. Lead most commonly occurs as the mineral galena (lead sulfide [PbS]), and is sometimes found in other mineral forms.[2] Table A-1 in Appendix A includes a summary of the physical properties of lead.

For many of the uses in Cairo and elsewhere, lead must be hardened. Lead is hardened by alloying it with small amounts of arsenic, copper, antimony, or other metals. These alloys may then be used in manufacturing various lead-containing products. A list of typical end uses for lead alloys is given in Table A-2 of Appendix A. In addition to lead alloys, there are many lead compounds that may be used in the manufacture of lead-containing products. A list of the uses for select lead compounds is presented in Table A-3 of Appendix A. As can be seen from these tables, there are a large number of uses for lead, its alloys, and its compounds.

Though lead has many uses, it is also a toxic material that can adversely affect the blood, nervous system, brain, and kidneys. The principal routes of human exposure are ingestion and inhalation. Manifestations of lead exposure include anemia, encephalopathy, and kidney damage. Studies that investigate the environmental health risks to Cairo residents invariably conclude that lead is one of the area's major health hazards. Several references report ambient lead levels up to 10 $\mu g/m^3$ in many areas of Cairo and in the range of 10-50 $\mu g/m^3$ in industrial areas.[3] Studies of blood lead levels in Cairo residents report that some children, the most sensitive receptors in the population, have blood lead concentrations up to three times the WHO "safe" level.[4]

Though much has been done to reduce the ambient lead concentrations, there remain further opportunities for improvement. In order to implement policies with a goal of reducing the amount of ambient airborne lead, it is necessary to have an accurate lead emissions inventory that details the primary sources of ambient lead. With this information, sources can be prioritized and corrective actions can first be taken where they will have the greatest positive effect. This document is the initial attempt at an inventory of lead emissions from the major sources of lead emissions in the greater Cairo area. The inventory and associated database will provide a foundation on which to base regulatory strategies, conduct modeling exercises, and assess emissions trends.

2.2 Air Emission Inventory Methodology

The methodology for this initial inventory can be divided into three parts; source category selection, data collection, and emissions estimation methodology.

2.2.1 Source Category Selection

Given the number of uses for lead and its compounds, it can be correctly deduced that there are a large number of industries that may emit lead into the air. The USEPA has researched the subject and publishes a list of the industries, activities and practices that emit or may emit lead. The stationary (i.e., excluding mobile) sources found from the USEPA research are listed in Table 2 below.

An important step in reducing health risks due to lead exposure was taken when a lead additive was removed from gasoline sold in the greater Cairo area. This action reduced the exposure of the general public to lead emitted from mobile sources. Thus, stationary sources are thought to be the major remaining sources of lead emissions and are the focus of this inventory.

TABLE 2: STATIONARY SOURCE ACTIVITIES THAT MAY EMIT LEAD

List of Stationary Sources, Industries, and Practices that May Emit Lead and Lead Compounds[5]
Secondary Lead Smelting
Primary Copper Production
Secondary Copper Production
Primary Lead Smelting
Primary Zinc Smelting
Secondary Aluminum Operations
Iron and Steel Foundries
Ore Mining, Crushing, and Grinding
Brass and Bronze Processing
Stationary External Combustion Sources
Stationary Internal Combustion Sources
Municipal Waste Incineration
Industrial and Commercial Waste Incineration
Sewage Sludge Incineration
Medical Waste Incineration
Hazardous Waste Incineration
Drum and Barrel Reclamation
Burning of Scrap Tires
Crematories
Pulp and Paper Industry
Portland Cement Manufacturing
Pressed and Blown Glass Manufacturing
Lead-Acid Battery Production
Lead-Oxides in Pigments
Lead Cable Coating
Frit Manufacturing
Ceramics and Glazes
Solder Manufacturing
Electroplating
Stabilizers in Resins
Asphalt Concrete
Application of Paints
Shooting Ranges
Rubber Products

Note: Activities not necessarily present or applicable in greater Cairo area

Though these activities may each emit lead, it is beyond the scope of an initial emissions inventory to include every potential source of emissions. Rather, this emissions inventory will focus on the industries and activities that are felt to be most significant in the greater Cairo area. Based on monitoring data, preliminary emissions investigations, and the experience of the USEPA and local environmental professionals, it was felt that the most significant remaining sources of ambient lead emissions in Cairo are given in Table 3 below. As the inventory is updated in the future, it can be refined by including additional activities.

TABLE 3: STATIONARY SOURCES INCLUDED IN THIS EMISSIONS INVENTORY

List of Lead-Emitting Stationary Sources, Industries, and Activities Included in this Emissions Inventory
Secondary Lead Smelting
Lead-Acid Battery Production
Secondary Copper Production (including brass and bronze)
Portland Cement Manufacturing
Mazout Combustion

2.2.2 Data Collection

The development of an emission inventory for lead (or any other pollutant) in Egypt is confounded by the lack of data and resources to identify relevant facilities and obtain accurate, current process and production data. Some information on identification and characteristics of licensed facilities was obtained from the General Organization for Industrialization (GOFI), the Central Agency for Planning, Mobilization, and Statistics (CAPMAS), and the Environmental Map of Egypt prepared by the EEAA.[6] However, the most productive approach to data collection was facility-to-facility surveys. Many unlicensed facilities exist that can only be identified by this approach as there are no official records of their presence. Though the facility surveys are time consuming, they are an indispensable means of obtaining accurate, current, and comprehensive source data. The secondary lead smelting, lead-acid battery, copper, and Portland cement production data given in this report were obtained using facility surveys. This data, in its entirety, is included in the emissions inventory database created in conjunction with this report. Mazout usage data was obtained from the Ministry of Petroleum.

2.2.3 Emissions Estimation Methodology

An emission factor is a representative value that relates the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of lead emitted per metric ton of mazout burned). Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of the available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category (i.e., a population average).[7] In the absence of continuous emissions data, emission factors are frequently the best or only method available for estimating emissions, in spite of their limitations.

The general equation for emission estimation using an emission factor is:

$$E = A \times EF \times \left(\frac{1 - ER}{100} \right)$$

where:

E	= Emissions	EF	= Emission Factor
A	= Activity Rate	ER	= Overall Emission Reduction Efficiency, %

The emissions reduction efficiency can be accounted for either using the ER term in the equation above or by developing emission factors that incorporate the emissions reduction (as is done for Portland cement kilns). Note that, although there are a small number of air pollution control devices installed at the facilities surveyed, these are by and large ineffective or inoperable. Thus, for most facilities, no emissions reduction efficiency has been used in estimating emissions. The one exception is the Portland cement industry, which has efficient and operational control devices. Emissions reductions due to the use of this equipment has been accounted for in this industry, although it is not clear that the emissions control equipment is operated continuously.

Emissions of lead were calculated for each source using emission factors from three sources:

- *Compilation of Air Pollutant Emission Factors, Fifth Edition*, AP-42, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.
- Source tests performed in Cairo by the Cairo Air Improvement Project for the express purpose of developing emission factors for this report.
- Mass balance using materials information developed for this report.

The use and development of the emission factors are detailed in Appendix B of this report. It should be noted that emissions estimates rely not only upon the emission factors, but also upon reliable and accurate production data ("activity rate" in the equation above). The production data used to estimate emissions for this inventory comes primarily from the facility surveys. The survey requested actual production data for 1999. Where possible, this data was confirmed, however, it is not unreasonable to assume that some facility owners have under-reported the production from their facilities out of fear of additional taxation. Future refinements of this inventory may include additional checks of the accuracy of the reported production data.

2.3 Report Organization

Section 3 of this report includes a description of and the emissions from the activities included in this inventory. Section 4 is the conclusion and recommendations for future work. The appendices include general information on lead and lead compounds (Appendix A), detailed development of emission factors (Appendix B), and a description of the database associated with this report (Appendix C).

3 Stationary Source Emissions

3.1 Secondary Lead Smelting

The secondary lead smelting industry produces elemental lead and lead alloys by reclaiming lead. The primary source of the reclaimed lead is scrap automobile and truck batteries. Smelting is the reduction of lead compounds to elemental lead and requires a higher temperature than that required for melting lead. Rotary furnaces are typically used for smelting scrap lead and producing secondary lead. After processing in the rotary furnace, the secondary lead is typically refined in a kettle to produce soft lead, or refined and alloyed to produce hard lead. The typical sequence of operations at an Egyptian secondary lead smelting operation includes scrap receiving and preparation, rotary furnace smelting, lead refining and alloying, and casting. Battery breaking is also performed at a number of facilities (primarily the Awadallah facilities) and is undoubtedly a source of lead emissions. However, because of the variable nature of emissions from battery breaking, USEPA has elected not to develop an emission factor for this process. Given the relatively minor amount of emissions from battery breaking, the lead emissions from this process are not accounted for in this report. However, in the future it may be helpful to perform testing at an Awadallah facility and develop an emission factor. As battery breaking is performed primarily at the Awadallah facilities, an emission factor may be appropriate in Egypt while it may not be in the United States. A summary of 1999 emissions from this industry is provided in Table 4.

3.1.1 Rotary Furnace Smelting

A rotary furnace is typically a refractory-lined steel drum mounted on rollers with an electric motor to rotate the drum. Fuel is injected at one end of the drum, and the connection to the exhaust stack (if applicable) is often located at the same end. The furnaces are operated on a batch basis.

Emission factors were developed by CAIP through source testing at several facilities in Cairo. Two emission factors have been developed for this process. One is applicable at the Awadallah facilities, and the other is applicable at all other facilities. The Awadallah facilities produced nearly 75% of the total lead ingot in 1999 and consistently showed lower emissions from their rotary furnaces. It was felt that the most accurate portrayal of emissions from this process would result from separating the Awadallah facilities from the others. See Appendix B for more detail on the emission factor development. The emission factor for lead emissions from rotary furnaces at secondary lead smelters was applied directly to the annual production throughput to calculate annual emissions, as shown below. The production throughput for rotary furnaces is the amount of lead ingot produced.

Awadallah Facilities:

$$44{,}400\,\frac{\text{metric tons ingots}}{\text{year}}\times 21.4\,\frac{\text{kg lead emitted}}{\text{metric ton ingots}}=950{,}160\,\frac{\text{kg lead emitted}}{\text{year}}$$

Other Facilities:

$$15{,}540\,\frac{\text{metric tons ingots}}{\text{year}}\times 76.8\,\frac{\text{kg lead emitted}}{\text{metric ton ingots}}=1{,}193{,}472\,\frac{\text{kg lead emitted}}{\text{year}}$$

3.1.2 Kettle Refining Operations

After the secondary lead is produced from the rotary furnace it is typically cooled into bars that are then used as the feed stream for the kettle refining process. In this process, large, open-top, heated kettles are used to melt and refine the secondary lead. In some cases, smaller cauldrons are used in lieu of kettles, but the principal of operation is the same. This is also the step in the process where other metals such as antimony can be added to produce a desired lead alloy.

Emission factors were developed by CAIP through source testing at several facilities in Cairo. See Appendix B for more detail on the emission factor development. The emission factor for lead emissions from kettle refining operations at secondary lead smelters was applied directly to the annual production throughput to calculate annual emissions, as shown below. The production throughput for refining kettles is equivalent to the amount of refined lead ingots produced. One facility does not use refining kettles, but only rotary furnaces, which is why the throughput for this process is lower than that for the rotary furnace.

$$51{,}540\,\frac{\text{metric ton ingots}}{\text{year}} \times 0.63\,\frac{\text{kg lead emitted}}{\text{metric ton ingots}} = 32{,}470\,\frac{\text{kg lead emitted}}{\text{year}}$$

3.1.3 Casting

After the lead is refined in the refining/alloying kettles, it is typically poured into molds and allowed to cool. The pouring process is usually done by hand with one operator dipping a ladle into the refining kettle and pouring the molten lead into the mold. Another operator skims any impurities from the top of the molten lead as it cools and removes the hardened lead after the cooling process is complete. This is the often the final product from a secondary lead smelter.

The USEPA believes that casting of lead is a small, but not insignificant, source of lead emissions because the temperature of molten lead is well below the fuming temperature of lead. Visual inspection of select casting operations in Cairo confirmed that only a negligible amount of lead fumes was visible during the casting operation. Thus, it was felt that the AP-42 emission factor for lead casting was appropriate for use in Cairo.

The emission factor for lead emissions from casting processes at secondary lead smelters was applied directly to the annual production throughput to calculate annual emissions, as shown below. The production throughput for casting operations is equivalent to the amount of lead ingots produced. See Appendix B for more detail on the emission factor development.

$$59{,}940\,\frac{\text{metric ton ingots}}{\text{year}} \times 0.0074\,\frac{\text{kg lead emitted}}{\text{metric ton ingots}} = 444\,\frac{\text{kg lead emitted}}{\text{year}}$$

TABLE 4: SUMMARY OF LEAD EMISSIONS FROM SECONDARY LEAD SMELTING

Estimate of 1999 Lead Emissions from Secondary Lead Smelting Processes in the Greater Cairo Area

Process	**Annual Throughput** (metric ton ingot)	**1999 Lead Emissions** (metric ton)
Rotary Furnace Smelting	59,940	2,144
Kettle Refining Operations	51,540	32.5
Casting	59,940	0.44
Total		**2,177**

3.2 Lead-Acid Battery Production

One of the major uses of lead is for lead-acid storage batteries. The electrical systems of automobiles, trucks, ships, and aircraft depend upon such batteries for start-up. Lead-acid batteries are produced from lead alloy ingots often purchased from a secondary lead smelting operation and lead oxide. The typical production process includes grid casting, paste mixing, plate stacking, plate burning, and element assembly into the battery case (the latter three often called the "3-Process Operation"). A summary of 1999 emissions from this industry is provided in Table 5.

3.2.1 Grid Casting

Battery grids are manufactured using either a casting or a stamping operation. The casting operation is typical for the Cairo facilities. In this operation, lead alloy ingots are charged into a melting pot and the molten lead then flows into molds that form the battery grids. USEPA AP-42 emission factors for grid casting were used to estimate emissions. See Appendix B for more detail on the emission factor development. The emission factor was applied directly to the annual production throughput to calculate annual emissions, as shown below. The production throughput for grid casting is based primarily upon the amount of batteries produced although there were a few facilities that produced only battery plates and thus performed grid casting, but not the other processes associated with battery production. Because some facilities perform grid casting but do not assemble batteries, the production throughput for grid casting is slightly higher than that for the remaining processes in this industry.

$$421{,}400\,\frac{\text{batteries}}{\text{year}}\times 0.0004\,\frac{\text{kg lead emitted}}{\text{battery}} = 169\,\frac{\text{kg lead emitted}}{\text{year}}$$

3.2.2 Paste Mixing

The paste mixing operation is conducted in a batch-type mixer. A mixture of lead oxide powder, water, and sulfuric acid produces a positive paste. The negative paste is made with the same ingredients in slightly different proportions with the addition of an expander. The primary emissions seem to come from pouring the lead oxide into the mixing bowl and during the initial stages of the mixing process when the powder is not uniformly coated with the liquid components of the paste.

USEPA AP-42 emission factors for paste mixing were used to estimate emissions. See Appendix B for more detail on the emission factor development. The emission factor was applied directly to the annual production throughput to calculate annual emissions, as shown below. The production throughput for paste mixing is the amount of batteries produced.

$$416{,}600\,\frac{\text{batteries}}{\text{year}}\times 0.00113\,\frac{\text{kg lead emitted}}{\text{battery}} = 471\,\frac{\text{kg lead emitted}}{\text{year}}$$

3.2.3 3-Process Operation

The 3-process operation consists of plate stacking, plate burning, and element assembly. Plate stacking involves cutting the doublet plates apart and stacking the plates into an alternating positive and negative block formation with insulators between them. Leads are then welded on tabs on each positive or negative plate or in an element during the plate burning operation. After the elements have been placed into a battery case and the top is installed, battery posts are welded or cast in place.

USEPA AP-42 emission factors for the 3-process operation were used to estimate emissions. See Appendix B for more detail on the emission factor development. The emission factor was applied directly to the annual production throughput to calculate annual emissions, as shown below. The production throughput for the 3-process operation is the amount of batteries produced.

$$416{,}600\,\frac{\text{batteries}}{\text{year}} \times 0.0066\,\frac{\text{kg lead emitted}}{\text{battery}} = 2{,}750\,\frac{\text{kg lead emitted}}{\text{year}}$$

3.2.4 Small Parts Casting

There are also a number of facilities that produce small parts that are used in battery manufacturing. Typically, these are battery connectors that are short lead straps that connect the different cells of the battery. Though these facilities do not produce batteries, they have been included here because they are closely related.

USEPA AP-42 emission factors for the small parts casting were used to estimate emissions, although the emission factor was modified to reflect different measures of production. See Appendix B for more detail on the emission factor development. The emission factor was applied directly to the annual production throughput to calculate annual emissions, as shown below.

$$142.8\,\frac{\text{metric tons parts}}{\text{year}} \times 0.14\,\frac{\text{kg lead emitted}}{\text{metric ton parts}} = 20\,\frac{\text{kg lead emitted}}{\text{year}}$$

TABLE 5: SUMMARY OF LEAD EMISSIONS FROM LEAD-ACID BATTERY PRODUCTION

Estimate of 1999 Lead Emissions from Lead-Acid Battery Production in the Greater Cairo Area

Process	**Annual Production**	**1999 Lead Emissions** (metric ton)
Grid Casting	421.4 (1,000 bat./yr)	0.169
Paste Mixing	416.6 (1,000 bat./yr)	0.471
3-Process Operation	416.6 (1,000 bat./yr)	2.75
Small Parts Casting	142.8 (metric ton/yr)	0.020
Total		**3.41**

3.3 Secondary Copper Processing

Secondary copper processing involves the manufacture of copper, brass, and bronze from secondary sources such as machine shop punchings, turnings, and borings; defective or surplus goods; automobile radiators, pipes, wires, bushings, and bearings; and metallurgical process skimmings and dross.[7] The secondary copper produced in the greater Cairo area is typically refined into relatively pure copper or alloyed with zinc or tin to form brass or bronze.

The scrap used as feed stock in this industry often contains lead in varying amounts. This lead is primarily emitted from the tilting furnaces (of which there are very few in the greater Cairo area) and from the crucible furnaces.

3.3.1 Tilting Furnaces

A tilting furnace is very similar to a rotary furnace as used in the secondary lead smelting industry. It is typically a refractory-lined steel drum mounted on rollers with a motor to rotate the drum. Fuel is injected at one end of the drum, and the connection to the exhaust stack (if applicable) is often located at the same end. The furnaces are operated on a batch basis.

Because there are so few tilting furnaces at secondary copper processing facilities in the greater Cairo area, a source test provides little value. Therefore, the emission factor for tilting furnaces has been estimated to be equivalent to the emission factor from crucible furnaces in this industry. Because of the small number of tilting furnaces in the industry, this is an acceptable assumption, although future work could involve a source test on this type of equipment to confirm that the assumption is appropriate.

$$1{,}320\,\frac{\text{metric tons copper}}{\text{year}} \times 0.50\,\frac{\text{kg lead emitted}}{\text{metric ton copper}} = 660\,\frac{\text{kg lead emitted}}{\text{year}}$$

3.3.2 Crucible Furnaces

In this process, large, open-top, heated kettles are used to melt, alloy, and refine the secondary copper. In some cases, smaller, bathtub-shaped cauldrons are use, but the principal of operation is the same. The final product, either copper, brass, or bronze is poured from the crucible into molds where the castings cool.

Emission factors were developed by CAIP through source testing at several facilities in Cairo. See Appendix B for more detail on the emission factor development. The emission factor for lead emissions from crucible furnaces at secondary copper processing facilities was applied directly to the annual production throughput to calculate annual emissions, as shown below. The production throughput for crucible furnaces is assumed equivalent to the amount of product manufactured.

$$14{,}760\,\frac{\text{metric tons copper}}{\text{year}} \times 0.50\,\frac{\text{kg lead emitted}}{\text{metric ton copper}} = 7{,}380\,\frac{\text{kg lead emitted}}{\text{year}}$$

TABLE 6: SUMMARY OF LEAD EMISSIONS FROM SECONDAY COPPER PROCESSING

Estimate of 1999 Lead Emissions from Secondary Copper Processing in the Greater Cairo Area

Process	Annual Production (metric ton)	1999 Lead Emissions (metric ton)
Tilting Furnaces	1,320	0.66
Crucible Furnaces	14,760	7.38
Total	16,080	**8.04**

3.4 Portland Cement Manufacturing

The production of Portland cement can be divided into four major steps: raw material handling, kiln feed preparation, pyroprocessing, and cement grinding. Though there may be fugitive lead emissions as wind-blown particulate from the materials piles during materials handling and kiln feed preparation processes, these emissions are expected to be less significant than the lead emissions from the pyroprocessing operation.

Pyroprocessing is the heart of the Portland cement manufacturing process. During pyroprocessing, the raw material is transformed into clinkers, which resemble hard, gray aggregate. This transformation typically occurs in a rotary kiln, which is a long, cylindrical, slightly inclined, refractory-lined furnace.

Emissions of metals from Portland cement kilns can be grouped into three general classes: volatile metals, semivolatile metals (such as lead), and refractory metals. In general, the semivolatile metals tend to be discharged through the exhaust stack of the kiln. Most of the lead volatilized in the hot end of the kiln condenses into particulate matter as it cools and is exhausted. Some of the lead, however, will be incorporated into the clinker.

After the clinker is formed and cooled, a series of blending and grinding steps takes place to transform the clinker into Portland cement. Because much of the lead is exhausted from the kiln, the clinker grinding process is not felt to be a substantial source of lead emissions.[7]

3.4.1 Cement Kiln

Cement kilns are typically rotary kilns lined with refractory to protect the steel shell and retain heat. The raw material enters the kiln at the elevated end and is continuously and slowly moved to the lower end by rotation of the kiln. As the material moves down the kiln, it is changed to cementitious minerals as a result of the high temperature.

USEPA AP-42 emission factors for Portland cement kilns were used to estimate emissions. See Appendix B for more detail on the emission factor development. The emission factor was applied directly to the annual production throughput to calculate annual emissions, as shown below. The production throughput for refining kettles is assumed equivalent to the amount of clinker produced.

<u>Cement Kilns with Electrostatic Precipitator</u>

$$9{,}015{,}500\,\frac{\text{metric tons clinker}}{\text{year}} \times 0.00036\,\frac{\text{kg lead emitted}}{\text{metric ton clinker}} = 3{,}246\,\frac{\text{kg lead emitted}}{\text{year}}$$

<u>Cement Kilns with Baghouse (Fabric Filter)</u>

$$3{,}723{,}000\,\frac{\text{metric tons clinker}}{\text{year}} \times 0.000038\,\frac{\text{kg lead emitted}}{\text{metric ton clinker}} = 142\,\frac{\text{kg lead emitted}}{\text{year}}$$

TABLE 7: SUMMARY OF LEAD EMISSIONS FROM PORTLAND CEMENT MANUFACTURING

Estimate of 1999 Lead Emissions from Portland Cement Manufacturing in the Greater Cairo Area

Process	**Annual Production** (metric tons cement per year)	**1999 Lead Emissions** (metric ton)
Cement Kiln	~13,500,000	3.39
Total		**3.39**

3.5 Mazout Combustion

Mazout is a fuel used for a variety of purposes throughout Egypt. Of the fuels used in significant quantity in the greater Cairo area, mazout is believed to have the highest lead content. Because no data was available on the lead content of mazout, CAIP retrieved samples of the mazout and had them tested. The results of these tests are detailed in Appendix B.

3.5.1 Mazout Combustion

The amount of mazout combusted in 1999 was obtained from the Ministry of Petroleum. The development of the emission factor for mazout combustion is described in Appendix B.

$$4{,}180{,}000\,\frac{\text{metric tons mazout}}{\text{year}} \times 0.114\,\frac{\text{kg lead emitted}}{\text{metric ton mazout}} = 476{,}520\,\frac{\text{kg lead emitted}}{\text{year}}$$

TABLE 8: SUMMARY OF LEAD EMISSIONS FROM MAZOUT COMBUSTION

Estimate of 1999 Lead Emissions from Mazout Combustion in the Greater Cairo Area

Process	**Annual Production** (metric tons mazout)	**1999 Lead Emissions** (metric ton)
Mazout Combustion	4,180,000	477
Total		**477**

4 Conclusion

4.1 Conclusions

The work described in this report is the initial lead emissions inventory for the greater Cairo area. The study has developed the most comprehensive database of lead-emissions, related process data, and production data available at this time. The results of the study clearly show that secondary lead smelters, and in particular rotary furnaces at these facilities, are very significant sources of lead emissions within the area. Future updates to the emissions inventory will show the effects of ongoing efforts to reduce lead emissions in the greater Cairo area.

4.2 Future Work

This emission inventory represents a reasonably comprehensive accounting of the major lead-emitting sources in the greater Cairo area in 1999. However, an emissions inventory represents only a snapshot of emissions over a given geographical area at a given time. For the emissions inventory to be most useful, it must be part of an ongoing emissions inventory program including annual emissions inventory updates. Only with updated data can the effects of efforts at reducing lead emissions truly be seen.

As is the nature of emissions inventories everywhere, there remains a wish list of items that can be included in future years to improve and refine the data. The authors provide the following suggestions for following years:

- Confirm the accuracy of USEPA AP-42 emission factors from Portland cement kilns in Egypt. A source test is recommended. Establish that the control devices are in operation at all times or as much as is practicable.
- Develop an emission factor for battery breaking at he Awadallah facilities and estimate emissions from same.
- Review the list of secondary lead smelters used in the database to ensure that the list is comprehensive.
- Perform more testing of the lead content of mazout. Be certain to use a lab that fully understands the difficulties in testing this material and suggest that microwave digestion be used in the sample preparation process. There were some conflicting lab results concerning the amount of lead in mazout that were not included in this report.
- Improve the emission factor from refining kettles at secondary lead smelters by performing another source test from this process.
- Broaden the scope of lead emissions sources in the inventory and the associated database. Consider lead oxide manufacturing.
- Review the list of secondary lead smelters in the associated database. Some of these facilities ceased operations near the end of 1999 and should be removed from subsequent emissions inventories.

These additions and refinements, as part of an ongoing lead emissions inventory program, will ensure that the regulatory community has the data upon which to base sound environmental policy for years to come.

4.3 Acknowledgements

The Cairo Air Improvement Project (CAIP) is being conducted under the auspices of the Egyptian Environmental Affairs Agency and the Office for Energy Planning. The project is funded by the U.S. Agency for International Development under Contract No. 263-C-00-97-00090-00.

A consortium assembled and managed by Chemonics International is performing the Cairo Air Improvement Project. Mr. Gilbert Richard, Chemonics International, is the Chief of Party for the project.

Dr. Ibrahiem Abdel Gelil and Dr. Ahmed Gamal are responsible for administration of the CAIP within the EEAA. Mrs. Elzadia Washington is the USAID technical representative for the project.

4.4 Disclaimer

The opinions and conclusions stated in this report are those of the authors and do not necessarily represent those of USAID, EEAA, OEP, or any of the consulting organizations involved in the conduct of the program.

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[1] *The Merck Index: An Encyclopedia of Chemicals, Drugs, and Biologicals*, 10th ed. Rathway, New Jersey: Merck and Company, Inc., 1976. p. 776.

[2] Greninger, D., V. Kollonotsch, and C. H. Kline (Charles H. Kline & Co., Inc.). *Lead Chemicals*. New York, New York: International Lead Zinc Research Organization, Inc. (ILZRO), 1975.

[3] Environmental Studies Department, Institute of Graduate Studies and Research, University of Alexandria (Egypt), *A Comparative Study on the Contribution of Lead Emission from Motor Vehicles to Atmospheric Pollution*, A Consultancy Study for the Ministry of Petroleum. Cairo, 1996.

[4] Sessions, S. M. Gaffen, S. Moore, R. Efroymson, F. El-Gohary, M. Nasralla, A. El-Gamal, and A. Abdel Gawaad, “Comparing Environmental Health Risks in Cairo, Egypt, Volume 1: Final Report,” prepared for USAID/NE/DR/ENR by Chemonics International and its Associates. Cairo, 1994.

[5] Office of Air Quality Planning and Standards, Office of Air and Radiation, U.S. Environmental Protection Agency, *Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds*. Research Triangle Park, North Carolina. May, 1998.

[6] Cabinet of Ministers, Egyptian Environmental Affairs Agency, Technical Cooperation Office for the Environment, *Lead Smelting in Egypt-Baseline Study (Private Lead Smelters in Greater Cairo)*. Cairo, 1996.

[7] Office of Air Quality Planning and Standards, Office of Air and Radiation, U.S. Environmental Protection Agency, *Compilation of Air Pollutant Emission Factors, Fifth Edition, AP-42*. Research Triangle Park, North Carolina.

Appendix A

Properties and Uses of Lead and Lead Compounds

TABLE A-1: PHYSICAL PROPERTIES OF LEAD

Physical Properties of Lead[1]

Property	Value
Atomic Weight	207.2g
Melting Point	327°C
Boiling Point	1170°C
Specific Gravity	
20°C	11.35 g/cm^3
327°C(solid)	11.00 g/cm^3
327°C(liquid)	10.67 g/cm^3
Specific heat	130 (J/kg-K)
Latent heat of fusion	25 J/g
Latent heat of vaporization	860 J/g
Vapor Pressure	
980°C	0.133 kPa
1160°C	1.33 kPa
1420°C	13.33 kPa
1500°C	26.7 kPa
1600°C	53.3 kPa

TABLE A-2: USES OF LEAD ALLOYS

Typical Uses of Various Lead Alloys[2]

Alloy	**Uses**
Lead-Copper	
<0.10%copper by wt.	Lead Sheet Lead Pipes Sheathing for electric power cables Wire and other fabricated lead products Tank linings Tubes for acid-mist precipitators Steam heating pipes for acid-plating baths
60-70% copper by wt. (leaded brass or bronze)	Bearings and bushings
Lead-Antimony	Lead-Acid battery positive grids, posts, and connectors Flashings and roofing materials Cable sheathings Ammunition Tank linings, pumps, valves, pipes, and heating and cooling coils in chemical operations using sulfuric acid or sulfate solutions at elevated temperatures Lead sheet Anodes in metal-plating and metal-electrowinning operations Collapsible tubes Wheel balancing weights for automobiles and trucks Special weights and castings Battery cable clamps
Lead-Antimony-Tin	Printing-type metals Bushings and sleeve bearings Journal bearings in freight cars and mobile cranes Decorative, slush, and special castings (e.g., miniature figures, casket trim, belt buckles, trophies, and holloware)
Lead-Tin	Solders for sealing and joining metals (e.g., electronic applications including printed circuit boards) Automobile radiators High temperature heat exchangers Terne-steel sheets for radio and television chassis, roofs, fuel tanks, air filters, oil filters, gaskets, metal furniture, gutters, and downspouts Coating of copper sheet used for building flashings Coating of steel and copper electronic components Electroplating
Lead-Calcium	Grids for large stationary stand-by power, submarine, and specialty sealed batteries Original equipment automotive batteries Negative grids for replacement batteries Electrowinning anodes Cable sheathing, sleeving for cable splices, specialty boat keels, and lead-alloy tapes
Lead-Calcium-Aluminum	Negative battery grids
Lead-Calcium-Tin	Maintenance-free automotive battery grids Electrowinning anodes

(cont.)

TABLE A-2: USES OF LEAD ALLOYS

Typical Uses of Various Lead Alloys[2]

Alloy	Uses
Lead-Silver	Insoluble anodes for zinc and manganese electroplating Anodes in the d-c cathodic protection of steel pipe and structures used in fresh, brackish, or seawater Solder in high pressure, high temperature cooling systems Positive grids of lead-acid batteries Soft solders
Lead-Silver-Antimony	Production of thin copper foil for electronics
Lead-Silver-Calcium	Zinc Electrowinning
Lead-Strontium-Tin	Maintenance-free battery grids
Lead-Tellurium	Used in pipes and sheets for chemical installations Shielding for nuclear reactors Cable sheathing
Fusible (lead, cadmium, bismuth, and tin in varying compositions)	Fuses Low-melting sprinkler systems Foundry patterns Molds, dies, punches, chucks, cores, mandrels, flexible tubing, and low-temperature solder
Lead-Idium	Used to solder metals to glass
Lead-Lithium and Lead-Lithium-Tin	Battery grids Bearings

TABLE A-3: USES OF LEAD COMPOUNDS

Typical Uses of Various Lead Compounds[3]

Compound	Uses
Lead acetate	Dyeing of textiles, waterproofing, varnishes, lead dryers, chrome pigments, gold cyanidation process, insecticide, anti-fouling paints, analytical reagant, hair dye
Lead alkyl, mixed	Anti-knock agent in fuel (primarily aviation gasoline)
Lead antimonate	Staining glass, crockery, and porcelain
Lead arsenate	Insecticide, herbicide
Lead arsenite	Insecticide
Lead azide	Primary detonating compound for high explosives
Lead borate	Varnish and paint dryer, waterproofing paints, lead glass, electrically conductive ceramic coatings
Lead borosilicate	A constituent of optical glass
Lead carbonate	Exterior paint pigments, ceramic glazes
Lead chloride	Preparation of lead salts, lead chromate pigments, analytical reagent
Lead chromate	Pigment in industrial paints, rubber, plastics, ceramic coatings, organic analysis
Lead cyanide	Metallurgy
Lead dimethyldithiocarbamate	Vulcanization accelerator with litharge
Lead dioxide	Oxidizing agent, electrodes, lead-acid storage batteries, curing agent for polysulfide elastomers, textiles, matches, explosives, analytical reagent
Lead fluoborate	Salt for electroplating lead; can be mixed with stannous fluoborate to electroplate any composition of tin and lead as an alloy
Lead fluoride	Electronic and optical applications, starting materials for growing single-crystal solid-state lasers, high temperature dry film lubricants
Lead fluosilicate	Solution for electrorefining lead
Lead formate	Reagent in analytical determinations
Lead hydroxide	Lead salts, lead dioxide
Lead iodide	Bronzing, printing, photography, cloud seeding
Lead linoleate	Medicine, drier in paints and varnishes
Lead maleate, tribasic	Vulcanizing agent for chlorosulfonated polyethylene
Lead molybdate	Analytical chemistry, pigments
Lead β-naphthalenesulfonate	Organic preparations
Lead naphthenate	Paint and varnish drier, wood preservative, insecticide, lube oil additive
Lead nitrate	Lead salts, mordant in dyeing and printing calico, matches, mordant for staining mother of pearl, oxidizer in the dye industry, sensitizer in photography, explosives, tanning, process engraving, lithography
Lead oleate	Varnishes, lacquers, paint drier, high-pressure lubricants

(cont.)

TABLE A-3: USES OF LEAD COMPOUNDS

Typical Uses of Various Lead Compounds[3]

Compound	Uses
Lead oxide, red	Storage batteries, glass, pottery, enameling, varnish, purification of alcohol, packing pipe joints, metal-protective paints, fluxes, and ceramic glazes
Lead phosphate	Stabilizing agents in plastics
Lead phosphate, dibasic	Imparting heat resistance and pearlescence to select plastics
Lead phosphite, dibasic	Heat and light stabilizer for vinyl plastics
Lead phthalate, dibasic	Heat and light stabilizer for general vinyl use
Lead resinate	Paint and varnish drier, textile waterproofing agent
Lead salicylate	Stabilizer or costabilizer for flooring and other vinyl compounds
Lead sesquioxide	Ceramics, ceramic cements, metallurgy, varnishes
Lead silicate	Ceramics, fireproofing fabrics
Lead silicate, basic	Pigment in industrial paints
Lead siliochromate	Coatings, primers, and finishes.
Lead sodium thiosulfate	Matches
Lead stannate	Additive in ceramic capacitors, pyrotechnics
Lead stearate	Varnish and lacquer drier, high-pressure lubricants, lubricant in extrusion processes, stabilizer for vinyl polymers, corrosion inhibitor for petroleum, component of greases, waxes, and paints
Lead subacetate	Decolorizing agent
Lead suboxide	Storage batteries
Lead sulfate	Storage batteries, paint pigments
Lead sulfate, basic	Paints, ceramics, pigments
Lead sulfate, blue basic	Structural-metal priming paints, rust inhibitor in paints, lubricants, vinyl plastics
Lead sulfate, tribasic	Electrical and other vinyl compounds with high heat stability
Lead sulfide	Ceramics, infrared radiation detector, semi-conductor, ceramic glaze
Lead telluride	Single crystals used as photoconductor and semiconductor in thermocouples
Lead tetraacetate	Oxidizing agent in organic synthesis, laboratory reagent
Lead thiocyanate	Ingredient of priming mix for small-arms cartridges, safety matches, dyeing
Lead titanate	Industrial paint pigment
Lead tungstate	Pigment
Lead vanadate	Preparation of vanadium compounds, pigment
Lead zirconate titanate	Element in hi-fi sets, transducer for ultrasonic cleaners, ferroelectric memory units
Litharge	Storage batteries, ceramic cements, fluxes, pottery, glazes, glass, chromium pigments, oil refining, varnishes, paints, enamels, assay of precious metal ores, manufacture of red lead, cement, acid resisting compositions, match-head compositions, rubber accelerator

[1] *Kirk-Othmer Encyclopedia of Chemical Technology.* 3rd ed. Volume 14. New York, New York: McGraw-Hill Book Company, 1974. P. 681.

[2] Sutherland, C.A., E.F. Milner, R.C. Kerby, and H. Teindl. Lead. *Ullmann's Encyclopedia of Industrial Chemistry*. 5th ed. Volume A15. B. Elvers, H. Hawkins, and Schultz, G. eds. Federal Republic of Germany: VCH, 1989. Pp. 193 to 247

[3] Hawley's Condensed Chemical Dictionary. 12th ed. R.J. Lewis, Sr., ed. New York, New York: Von Nostrand Reinhold, 1993. pp. 686 to 693.

Appendix B

Development of Emission Factors

Lead Emission Factor Development for Secondary Lead Smelting

The secondary lead smelting industry in Cairo consists of three primary processes. These include the smelting of lead in rotary furnaces, refining of lead in refining kettles, and casting of lead. The USEPA has not determined an emission factor for rotary lead smelting furnaces. Therefore, a source-testing program was completed to develop an appropriate emission factor for the typical lead smelting processes in Cairo, with particular focus on rotary furnaces. Though more tests were performed, some tests were clearly not representative of the industry and/or had production data that could not be confirmed making it impossible to relate emissions to production. Those results of the source test program that are acceptable for the purpose of emission factor development are presented in table B.1.

TABLE B.1

Results of Source Tests of Secondary Lead Smelters in the Cairo Area

Process	Facility	Particulate Emissions (kg/metric ton of Lead Processed)	Lead Emissions (kg/metric ton of Lead Processed)
Rotary Smelting Furnace	Ahmed Osman in Arab Abu Saaid	104.4	75.5
	Ahmed Osman #2 in Arab Abu Saaid	433	217
	Awadallah in Shobra Khema	24.1	19.4
	Awadallah in Arab Abul Saaied[1]	19.8	21.3
	Nabieh Abdel Hamieed in Arab Abu Saaied	131.1	97.6
	Soudy in Arab Abu Saaid[2]	158	50.9
	Soudi in Shobra Kheima	36	30
	Average	**129**	**73.1**
Kettle Refining Process			
	Awadallah #2 in Shobra Khema	0.3434	0.2244
	El Mahy	1.869	0.97
	Average	**1.11**	**.60**

1. Lab results show lead particulate slightly greater than total particulate.
2. Emission factor determined using estimated product throughput

The lead emission factors calculated below for rotary furnaces and for kettle refining are the averages of the source tests performed plus 5% to account for emissions not captured by the emissions test. The 5% value is in agreement with USEPA practice for the industry though it may underestimate the fugitive portion of emissions in Cairo. Note that two emission factors have been developed for rotary furnaces. One emission factor has been developed for the Awadallah facilities using only Awadallah data, and one emission factor has been developed for the remaining facilities using the complete data set (including the Awadallah data). The Awadallah facilities produced nearly 75% of the total lead ingot in 1999 and consistently had lower emissions than the other, smaller, facilities. It was felt that the most accurate estimation of total lead emissions from the industry as a whole would be obtained by separating the Awadallah facilities. Although the data from the Ahmed Osman #2 facility appears significantly higher than the others, this test was repeated at a later date. The repeat testing confirmed the accuracy of the emissions from this facility.

The emission factor for lead casting is from the USEPA AP-42 document[a], and includes both the fugitive and point source portions. Note that the casting emission factor is rated "e" or "poor" by USEPA indicating that it was developed from a very small number of facilities that may not be representative of the industry. Although casting appears to be a relatively minor source of emissions due to the fact that the molten lead is below the fuming temperature, further work may be helpful to refine this emission factor.

<u>Lead Emission Factors for Secondary Lead Smelting:</u>

Rotary Furnace (Awadallah facilities):

$$21.4\frac{\text{kg lead}}{\text{1,000 kg lead processed}}\quad\left(42.7\frac{\text{lb lead}}{\text{ton lead processed}}\right)$$

Rotary Furnace (Other facilities):

$$76.8\frac{\text{kg lead}}{\text{1,000 kg lead processed}}\quad\left(153\frac{\text{lb lead}}{\text{ton lead processed}}\right)$$

Kettle Refining: $0.63\frac{\text{kg lead}}{\text{1,000 kg lead processed}}\quad\left(1.25\frac{\text{lb lead}}{\text{ton lead processed}}\right)$

Casting: $0.0074\frac{\text{kg lead}}{\text{1,000 kg lead processed}}\quad\left(0.015\frac{\text{lb lead}}{\text{ton lead processed}}\right)$

[a] *Compilation of Air Pollutant Emission Factors, Fifth Edition*, AP-42, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

Lead Emission Factor Development for Lead-Acid Battery Manufacturing

The lead-acid battery manufacturing industry in Cairo consists of three primary processes that generate lead emissions. These include the grid casting molten lead to form battery plates, paste mixing to manufacture the lead oxide paste, and the so-called "three-process operation" that includes battery plate stacking, plate "burning" and element assembly. All emission factors are from USEPA AP-42.[b] In cases where AP-42 provides a range of emission factors, the higher value has been selected.

Lead Emission Factors for Lead-Acid Battery Manufacturing:

Grid Casting: $0.40 \dfrac{\text{kg lead}}{\text{1,000 batteries}} \quad \left(0.90 \dfrac{\text{lb lead}}{\text{1,000 batteries}}\right)$

Paste Mixing: $1.13 \dfrac{\text{kg lead}}{\text{1,000 batteries}} \quad \left(2.49 \dfrac{\text{lb lead}}{\text{1,000 batteries}}\right)$

3-Process Operation: $6.60 \dfrac{\text{kg lead}}{\text{1,000 batteries}} \quad \left(14.60 \dfrac{\text{lb lead}}{\text{1,000 batteries}}\right)$

There are also a number of facilities that produce small parts that are used in battery manufacturing. Typically, these are battery connectors that are short lead straps that connect the different cells of the battery. For the purpose of this inventory, the facilities that produce these small battery parts have been included in the lead-acid battery manufacturing industry. Production at these facilities is typically measured in metric tons of parts per year whereas the USEPA emission factor for small parts casting is provided in terms of batteries produced per year. The emission factor has been adjusted as shown below.

Small Parts Casting:

$$0.00005 \frac{\text{kg lead emitted}}{\text{battery produced}} \times \frac{\text{battery produced}}{\text{2 parts}} \times \frac{\text{1 part}}{\text{0.175 kg parts}} \times \frac{\text{1000 kg parts}}{\text{metric ton parts}} =$$

$$0.14 \frac{\text{kg lead emitted}}{\text{metric ton parts produced}}$$

[b] *Compilation of Air Pollutant Emission Factors, Fifth Edition*, AP-42, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

Lead Emission Factor Development for Secondary Copper Processing

The secondary copper processing industry in Cairo consists of three primary processes. These are smelting of copper in tilting furnaces, performing the same process in crucible furnaces, and casting. A source-testing program was instituted in Cairo to establish an estimate of lead emissions from the crucible furnace process. These results are included in Table B.2.

TABLE B.2
Results of Source Tests at Secondary Copper Processing Facilities in the Cairo Area

Process	Facility	Particulate Emission Factor (kg/metric ton of Copper Processed)	Lead Emission Factor (kg/metric ton of Copper Processed)
Crucible Furnace	5 Stars Copper Casting in Basateen	33.89	0.974
	Gold Foundry in Giza	6.32	0.510
	Ahmed Metwally in El Tonsi (test AMF-1)	17.6	0.31
	Ahmed Metwally in El Tonsi (test AMF-2)	11.8	0.21
	Average	**17.4**	**0.50**

Because there are so few tilting furnaces at secondary copper processing facilities in the greater Cairo area, a source test provides little value. Therefore, the emission factor for tilting furnaces has been estimated to be equivalent to the emission factor from crucible furnaces in this industry. Because of the small number of tilting furnaces in the industry, this is an acceptable assumption, although future work could involve a source test on this type of equipment to confirm that the assumption is appropriate. Emissions of lead from the casting process are assumed to be negligible.

Emission Factors for Secondary Copper Processing:

Tilting Furnace: $$0.50 \frac{\text{kg lead}}{\text{1,000 kg copper processed}} \quad \left(0.99 \frac{\text{lb lead}}{\text{ton copper processed}}\right)$$

Crucible Furnace: $$0.50 \frac{\text{kg lead}}{\text{1,000 kg copper processed}} \quad \left(0.99 \frac{\text{lb lead}}{\text{ton copper processed}}\right)$$

The lead emissions from secondary copper processing are very dependent upon the feed stock. In order to understand how variable the lead content is, castings were obtained from most of the secondary copper processing facilities. A selection of these samples was then sent to a local laboratory where the lead content was determined. The results of this analysis are included in the table below. Note that this information was not used in the development of the lead emission factor and is presented here only to provide a general idea of the variability of lead content in the products from this industry. Note also that the sample from the Fauzie Abd El-Latief El Saied facility appeared to be copper, whereas the remainder of the samples appeared to be brass or bronze.

TABLE B.3

Results of Analysis of Lead Content of Products from Secondary Copper Processing Industry

Facility	Sample ID	Lead Concentration (mg/g)
Saied Salieh Mostafa	01/003/057	32.059
Samiy Abd Alla Mohamed Sakr	01/003/115	20.352
Mohamed Mahmoud Mostafa	07/003/009	37.143
Rosa Abdel Malak Shnoda	09/034/005	32.215
Abu El-Magd Bauomi Mohamed	12/003/025	24.542
Hasanien Khalil Azam	12/003/150	6.125
Fauzie Abd El-Latief El-Saied	12/003/171	0.011
Saied Khalil Ibrahim	13/003/021	26.665
Mohmed Mostafa Hikal	14/003/020	25.185
Ali Mohamed Ali	15/003/010	24.103
Gamal Eied Hamied	15/003/029	16.134
Hassan Abdel Kadar	16/003/059	43.260
Ahmed Arafa	16/043/021	29.456
Abdel Hamied Ahmed Soultan	17/043/002	26.254
Soliman Hassan Soliman	17/431/054	35.952
Hamdie Ibrahim Kasab	18/003/007	16.789
Hossien Abu El-Soaood Ahmed	18/003/025	54.451
Abdel Rahman Mohamed Ali	18/003/038	27.378
Ramadan Hassan Khalil	18/003/045	16.575
Mohamed Zienhom Abd El-Aziz	18/003/073	24.282
Nabil Saied Ahmed	20/003/015	28.887
Mohamed Abdel Fatah	20/003/024	19.717
Mohmed Mohamed Abd El-Aal	20/003/034	38.084
Ahmed Hamdi Bauomie	20/003/043	79.867
Mohamed Hassan Abu Seriaa	20/003/050	23.841
Ahmed Mostafa Mostafa	20/043/037	32.468

Lead Emission Factor Development for Portland Cement Manufacturing

The Portland cement manufacturing process can be divided into raw materials handling, kiln feed preparation, pyroprocessing, and finished cement grinding. The primary focus is upon emissions from the pyroprocessing operations (the kilns), which constitute the core of a Portland cement plant. Pyroprocessing in the greater Cairo area is accomplished using the wet and the dry processes. In the dry process, raw materials are fed into the rotary kiln in a dry state, whereas in the wet process, the raw materials are mixed with water to form a slurry before being fed into the kiln.

The USEPA AP-42 document provides emission factors for lead emissions from Portland cement kilns having either an electrostatic precipitator or a fabric filter control device[c]. The EPA Locating and Estimating (L&E) document[d] provides additional factors for kilns not having control equipment. The appropriate emission factor has been used for each kiln in the greater Cairo area.

Emission Factors for Portland Cement Manufacturing:

Cement Kiln with no Control Equipment:

$$6.00x10^{-2}\frac{\text{kg lead}}{\text{1,000 kg clinker produced}} \quad \left(0.120\frac{\text{lb lead}}{\text{ton clinker produced}}\right)$$

Cement Kiln with Fabric Filter Control:

$$3.8x10^{-5}\frac{\text{kg lead}}{\text{1,000 kg clinker produced}} \quad \left(7.5x10^{-5}\frac{\text{lb lead}}{\text{ton clinker produced}}\right)$$

Cement Kiln with Electrostatic Precipitator Control:

$$3.6x10^{-4}\frac{\text{kg lead}}{\text{1,000 kg clinker produced}} \quad \left(7.1x10^{-4}\frac{\text{lb lead}}{\text{ton clinker produced}}\right)$$

There was some initial concern that the raw materials in Egypt may vary significantly in lead content from the raw materials used in the United States. If this were the case, it would not be appropriate to use the USEPA emission factor. Samples of Egyptian and U.S. cement were tested for lead content, and were found to be similar. Thus, the use of the USEPA emission factor seems appropriate. The results of the testing are summarized in the Table B.4.

Although the AP-42 emission factors have been used, it should be noted that they have a "D" rating indicating that EPA believes the emission factors to be below average in accuracy. This means that the data may have come from a limited number of facilities, and that there may be some reason to suspect that there is variability within the industry. Thus the emission factor may not be representative of the industry as a whole.

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[c] *Compilation of Air Pollutant Emission Factors, Fifth Edition*, AP-42, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

[d] *Locating and Estimating Air Emissions from Sources of Lead and Lead Compounds*, May 1998, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

Further refinement of these emissions could occur as a result of a limited source-testing program in Egypt.

In addition, the USEPA AP-42 document provides an estimate of lead emissions from cement kilns, but does not provide lead emissions from related processes such as raw material and clinker grinding. Further research may establish whether these are significant sources of lead emissions in the greater Cairo area.

TABLE B.4

Lead Content of Cement Samples

Sample ID	Pb Concentration (mg/kg)
TOR-042600-C-1 (Egypt)	71.80
TOR-042600-C-2 (Egypt)	78.55
TOR-042600-C-3 (Egypt)	68.80
US-RI-050300-IP-C (USA)	76.65

Lead Emission Factor Development for Mazout Combustion

The emission factor for mazout combustion was developed using an analysis of the fuel. Samples of mazout from the Greater Cairo Area were collected and analyzed for lead content. These results are summarized in Table B.5.

TABLE B.5
Lead Content of Mazout Samples

Sample ID	Pb Concentration (mg/kg)
SLS-AS-081099	120
SLS-AS-081099	110
KDBP-080899	41
KDBP-080899	37
AOLS-080899	222
AOLS-080899	205
NAHLS-091999	87
NAHLS-091999	93
Average	**114**

Though combustion technique will have an effect upon lead emissions because some lead may concentrate in any bottom ash or slag that may be generated, this effect is assumed to be negligible for mazout combustion in the greater Cairo area. Rather, it has been assumed that 100% of the lead present in the fuel will be emitted. The emission factor used is the average of the sampled lead concentrations. Further work may focus on the different combustion techniques used and their effect upon total lead emissions. In addition, more samples may be taken to further refine the average lead concentration.

Emission Factor for Mazout Combustion:

$$114\,\frac{\text{mg lead}}{\text{kg mazout combusted}}\quad\left(0.89\,\frac{\text{lb lead}}{\text{1,000 gal mazout combusted}}\right)$$

Though the USEPA has not developed emission factors for mazout combustion, external combustion emission factors for residual oil #6 and waste oil have been developed. These emission factors range from approximately 0.0015 pounds of lead per thousand gallons of residual oil #6 combusted to 1.68 pounds of lead per thousand gallons of waste oil combusted.[e]

[e] *Compilation of Air Pollutant Emission Factors, Fifth Edition*, AP-42, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

Appendix C

Emissions Inventory Database Functions

Background

The CAIP emission inventory team has developed a database using Microsoft Access 97 software. The database is includes detailed information on each known facility performing the activities thought to be large sources of lead emissions. This data includes a calculation of the estimated emission.

The database includes an inventory of lead pollutants in greater Cairo geographic area, which include governorates of Cairo, Giza, and Qaluobiya. This emission inventory database includes information on over two hundred facilities that perform one or more of the following activities:

- Secondary Lead Smelting
- Lead - Acid Battery Production
- Secondary Copper Production (including brass and bronze)
- Portland Cement Manufacturing

Note that the database does not include lead emissions from the combustion of mazout. This number was calculated for the report using the total mazout combustion in the greater Cairo area. To spread this value among the facilities and capture the total mazout combustion, every facility that combusts mazout would have to be entered into the database. This is beyond the capability of the database as it now exists. In the future, as more combustion sources are entered into the database, this will become more practical.

Database Structure

The database consists of three sections that enable a user to edit data, print reports, and print graphs. Note that to edit the database, the user must enter a user name of "admin" and a password of "admin". Printing reports and graphs may be done without a password.

System Edit

This section of the database requires a password to access. Once a valid password has been entered, the user has complete access to enter new facilities, change processes at existing facilities, and delete facilities.

Print Reports

This section of the database allows the user to print several preformatted reports including information from the database. A few example reports are attached for review.

Print Graphs

This section of the database allows the user to print several preformatted graphs using information from the database. Samples of the graphs are attached.